CLAIMS

What is claimed is:

1. An integrated optic gyroscope, comprising:
   (a) a bidirectional laser source formed on a compound semiconductor substrate and providing a lasing output from each end of the bidirectional laser source;
   (b) a pair of optical waveguide phase modulators formed on the compound semiconductor substrate to provide a phase modulation for each lasing output from the bidirectional laser source;
   (c) a plurality of passive optical waveguides formed on the compound semiconductor substrate to direct each lasing output to an edge of the compound semiconductor substrate after passing through one of the optical waveguide phase modulators;
   (d) a passive ring resonator adapted to receive each lasing output from the edge of the compound semiconductor substrate, to propagate each lasing output around the passive ring resonator in a different direction, and to direct a portion of each lasing output out of the passive ring resonator after propagating around the passive ring resonator; and
   (e) a pair of waveguide photodetectors formed on the compound semiconductor substrate and optically coupled to the edge of the compound semiconductor substrate, with the waveguide photodetectors receiving the portion of each lasing output from the passive ring resonator and generating therefrom electrical output signals wherefrom a rotation of the passive ring resonator can be determined.
2. The apparatus of Claim 1 wherein the passive ring resonator comprises an optical fiber.
3. The apparatus of Claim 2 further comprising a fiber optic splitter to couple each lasing output into the passive ring resonator and to couple the portion of each lasing output out of the passive ring resonator after propagating around the passive ring resonator.
4. The apparatus of Claim 1 wherein the passive ring resonator comprises a coiled optical waveguide formed on another substrate.

5. The apparatus of Claim 4 wherein the passive ring resonator further comprises an adiabatic mode-matching region located proximate to an edge of the substrate whereon the passive ring resonator is formed to optically couple the passive ring resonator to the passive optical waveguides on the compound semiconductor substrate.
6. The apparatus of Claim 4 wherein the coiled optical waveguide comprises a waveguide core of silicon nitride surrounded by a waveguide cladding of silica.
7. The apparatus of Claim 4 wherein the coiled optical waveguide includes a waveguide crossing.
8. The apparatus of Claim 4 wherein the coiled optical waveguide transmits the lasing output in a transverse-electric (TE) polarization state and suppresses any transmission of the lasing output in a transverse-magnetic (TM) polarization state.
9. The apparatus of Claim 4 wherein the passive ring resonator further includes a 2 x 2 evanescent waveguide coupler and a pair of 1 x 2 lateral mode interference splitters to couple each lasing output into the passive ring resonator, and to couple the portion of each lasing output out of the passive ring resonator after propagating around the passive ring resonator.
10. The apparatus of Claim 1 wherein the bidirectional laser source comprises a distributed feedback (DFB) laser.
11. The apparatus of Claim 1 wherein the bidirectional laser source and the pair of waveguide photodetectors comprise a plurality of compound semiconductor layers epitaxially deposited on the compound semiconductor substrate, with the plurality of compound semiconductor layers including at least one quantum well therein.
12. The apparatus of Claim 11 wherein the optical waveguide phase modulators and the passive optical waveguides are formed from the plurality of compound semiconductor layers with each quantum well therein being disordered or etched away at the locations of the optical waveguide phase modulators and at the locations of the passive optical waveguides.

13. The apparatus of Claim 11 wherein the bidirectional laser source is electrically isolated from each optical waveguide phase modulator by an ion-implanted region extending partway through the plurality of compound semiconductor layers.
14. The apparatus of Claim 4 wherein each substrate includes a plurality of alignment waveguides formed thereon.
15. The apparatus of Claim 4 wherein the two substrates are attached together edge-to-edge with a UV-cured epoxy adhesive.
16. The apparatus of Claim 1 wherein the compound semiconductor substrate further includes an alignment laser optically coupled to an alignment waveguide formed on the compound semiconductor substrate.
17. The apparatus of Claim 16 wherein the compound semiconductor substrate further includes an alignment photodetector optically coupled to the alignment waveguide on the compound semiconductor substrate.

18. An integrated optic gyroscope, comprising:
    (a) a passive ring resonator formed on a first substrate, with the passive ring resonator further comprising:
        (i) a coiled optical waveguide having a plurality of loops;
        (ii) a pair of input optical waveguides optically coupled to the coiled optical waveguide to receive lasing light from an edge of the first substrate and to convey the lasing light into the coiled optical waveguide in each of two counterpropagating directions; and
        (iii) a pair of output optical waveguides optically coupled to the coiled optical waveguide to receive a portion of the lasing light out from the coiled optical waveguide and to convey the portion of the lasing light to the edge of the first substrate after propagating around the coiled optical waveguide; and
    (b) a photonic integrated circuit formed on a second substrate, and further comprising:
        (i) a bidirectional distributed feedback (DFB) laser to generate the lasing light and to emit the lasing light from each end thereof;
        (ii) a pair of optical waveguide phase modulators optically coupled to each end of the DFB laser to provide a phase modulation for the lasing light;
        (iii) a passive optical waveguide to convey the lasing light from each optical waveguide phase modulator to an edge of the second substrate wherefrom the lasing light is coupled into the input optical waveguides on the first substrate; and
        (iv) a waveguide photodetector to receive the portion of the lasing light from each output optical waveguide on the first substrate and to generate therefrom an electrical output signal indicative of a rotation rate of the passive ring cavity.
19. The apparatus of Claim 18 wherein the first substrate comprises silicon, glass or quartz; and the second substrate comprises a III-V compound semiconductor.
20. The apparatus Claim 19 wherein the passive ring resonator, each input optical waveguide and each output optical waveguide comprise a waveguide core surrounded by a waveguide cladding of silica.

21. The apparatus of Claim 18 wherein the passive ring resonator is adapted to transmit the lasing light from the DFB laser in a transverse electric (TE) mode and to attenuate any transmission of the lasing light in a transverse magnetic (TM) mode.
22. The apparatus of Claim 18 wherein the input optical waveguides and the output optical waveguides are optically coupled to the coiled optical waveguide through a 2 x 2 evanescent waveguide coupler.
23. The apparatus of Claim 22 wherein the input optical waveguides and the output optical waveguides are further optically coupled to the coiled optical waveguide through a pair of 1 x 2 lateral mode interference splitters.
24. The apparatus of Claim 18 wherein each input optical waveguide and each output optical waveguide on the first substrate includes an adiabatic mode-matching region formed proximate to the edge of the first substrate.
25. The apparatus of Claim 18 wherein the coiled optical waveguide includes at least one waveguide crossing.
26. The apparatus of Claim 18 wherein the photonic integrated circuit further comprises a plurality of compound semiconductor layers epitaxially grown on the second substrate.
27. The apparatus of Claim 26 wherein the plurality of compound semiconductor layers comprise III-V compound semiconductor layers including a pair of low-refractive-index cladding layers sandwiched about a high-refractive-index core layer.
28. The apparatus of Claim 27 wherein the high-refractive-index core layer includes at least one quantum well therein.
29. The apparatus of Claim 28 wherein each quantum well is disordered within the pair of the optical waveguide phase modulators, and within each passive optical waveguide.
30. The apparatus of Claim 27 wherein one of the pair of low-refractive-index cladding layers includes a grating formed therein at the location of the DFB laser.
31. The apparatus of Claim 18 wherein an electrical isolation region is provided between each optical waveguide phase modulator and the DFB laser.
32. The apparatus of Claim 18 wherein the first and second substrates are attached together at the edges thereof.

33. The apparatus of Claim 32 wherein the first and second substrates include a plurality of alignment waveguides to align the input and output optical waveguides on the first substrate to the passive optical waveguides on the second substrate in preparation for attaching the first and second substrates together.

34. The apparatus of Claim 33 wherein the second substrate further includes an alignment laser optically coupled to at least one of the alignment waveguides on the second substrate.

35. The apparatus of Claim 33 wherein the second substrate further includes an alignment photodetector optically coupled to at least one of the alignment waveguides on the second substrate.

36. A method for forming an integrated optic gyroscope, comprising steps for:

(a) epitaxially growing on a compound semiconductor substrate a plurality of compound semiconductor layers including at least one quantum well layer;

(b) forming a plurality of active optical elements from the compound semiconductor layers including a bidirectional laser source and a pair of waveguide photodetectors;

(c) disordering or etching away a portion of the compound semiconductor layers and forming therefrom a pair of optical waveguide phase modulators optically coupled to the bidirectional laser source and a plurality of passive optical waveguides, with the passive optical waveguides connecting the pair of the optical waveguide phase modulators and the pair of waveguide photodetectors to an edge of the compound semiconductor substrate; and

(d) connecting a passive ring resonator to the edge of the compound semiconductor substrate, with the passive ring resonator being optically coupled to the plurality of passive optical waveguides to receive a phase-modulated lasing output from the laser source and each optical waveguide phase modulator, and to direct a portion of the phase-modulated lasing output to each waveguide photodetector after propagating the phase-modulated lasing output around the passive ring resonator.

37. The method of Claim 36 wherein the passive ring resonator comprises an optical fiber.

38. The method of Claim 36 wherein the passive ring resonator comprises a coiled optical waveguide formed on a silicon, glass or quartz substrate.

39. The method of Claim 36 wherein the step for connecting the passive ring resonator to the edge of the compound semiconductor substrate comprises attaching the passive ring resonator to the edge of the compound semiconductor substrate with an adhesive.